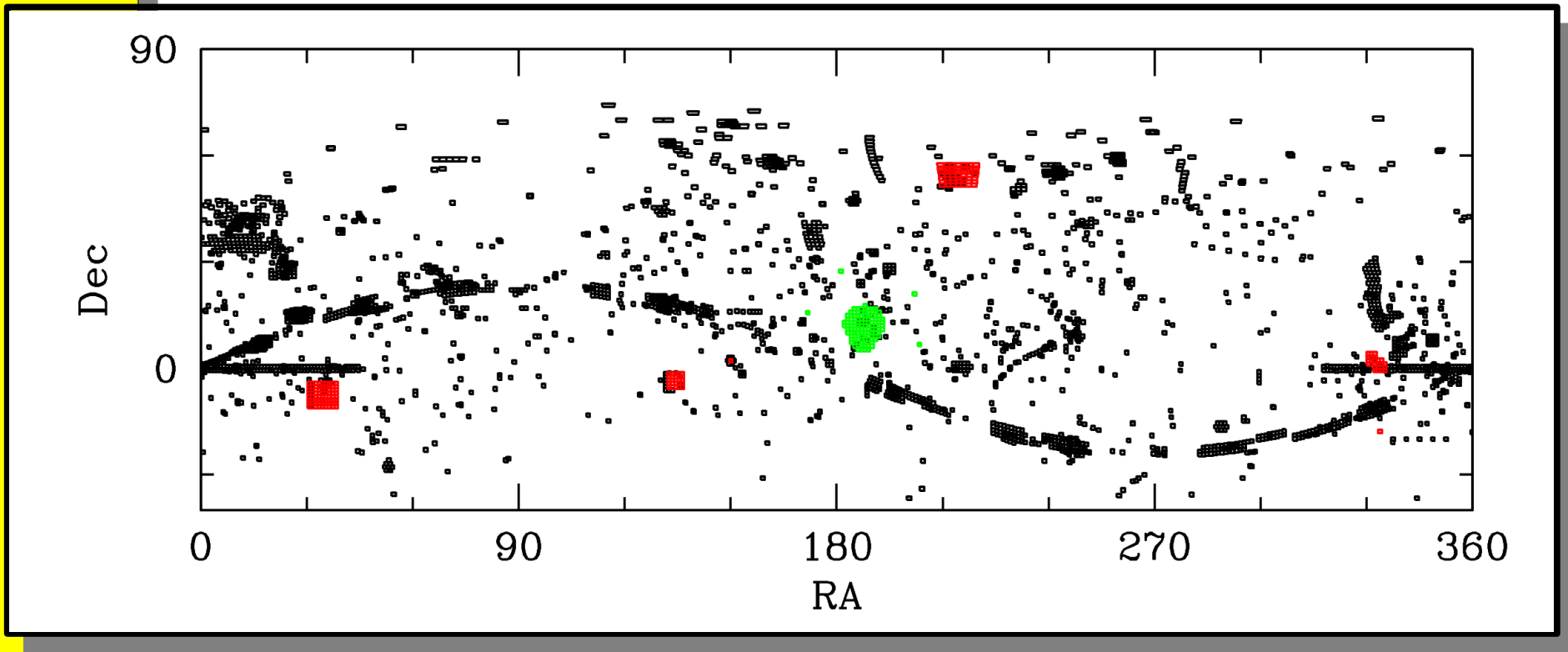
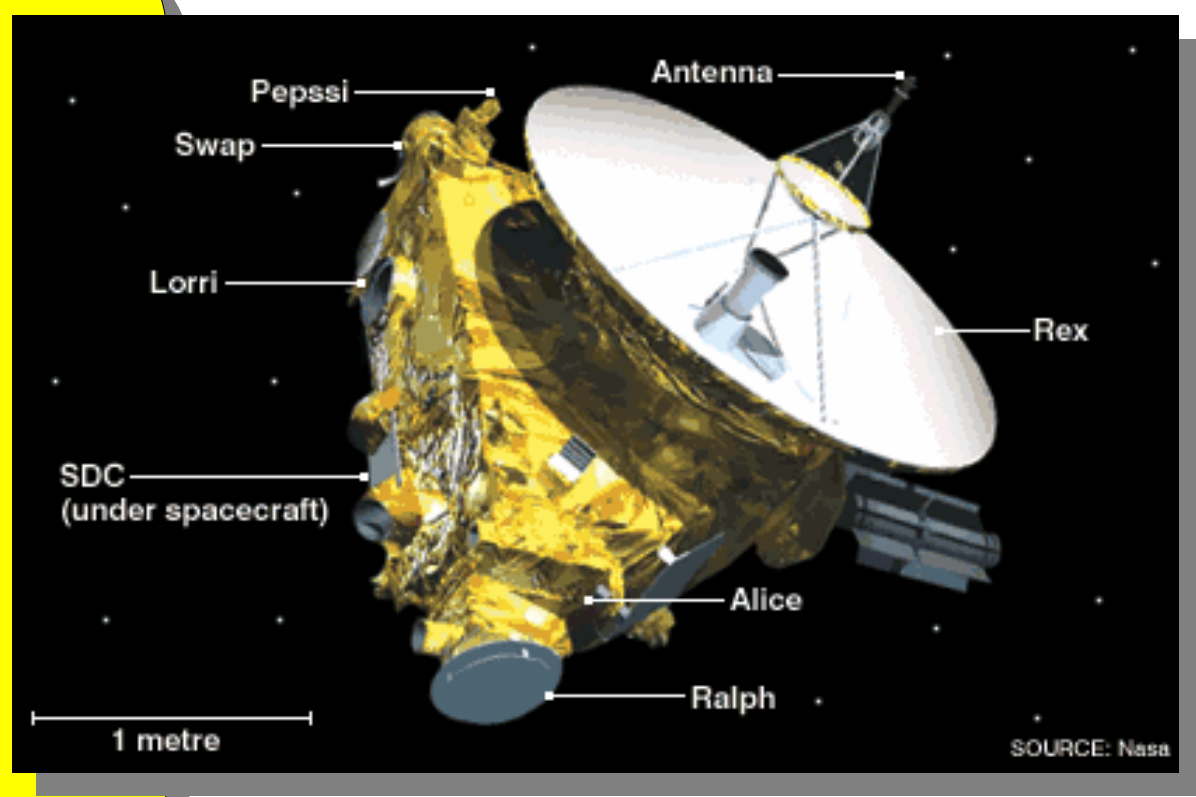


MegaPipe astrometry for the New Horizons spacecraft

Background:

New Horizons is a spacecraft launched by NASA to study Pluto. In 2015, on July 14, it will fly through the Pluto-Charon system for a few hours. It will then continue on to another Kuiper Belt object

MegaPipe is the CADC data processing pipeline for data taken with MegaCam (a 36 detector mosaic camera, FOV 1°) on CFHT. Starting in 2005, it has processed over 3000 square degrees of public and PI data



Abstract: The New Horizons spacecraft, launched by NASA in 2006, will arrive in the Pluto-Charon system on July 14, 2015. There it will spend a few hours imaging Pluto and its moons. It will then have a small amount of reserve propellant which will be used to direct the probe on to a second, yet to be discovered object in the Kuiper Belt. Data from the MegaPrime camera on the Canada-France-Hawaii Telescope was used to build a precise, high density astrometric reference frame for both the final approach into the Pluto system and the search for the secondary target. Pluto currently lies in the galactic plane. This is a hindrance in that there are potential problems with confusion. However, it also a benefit, since allows the use of the UCAC4 astrometric reference catalog, which is normally too sparse for use with MegaCam images. The astrometric accuracy of the final catalogs, as measured by the residuals, is 0.02 arcseconds.

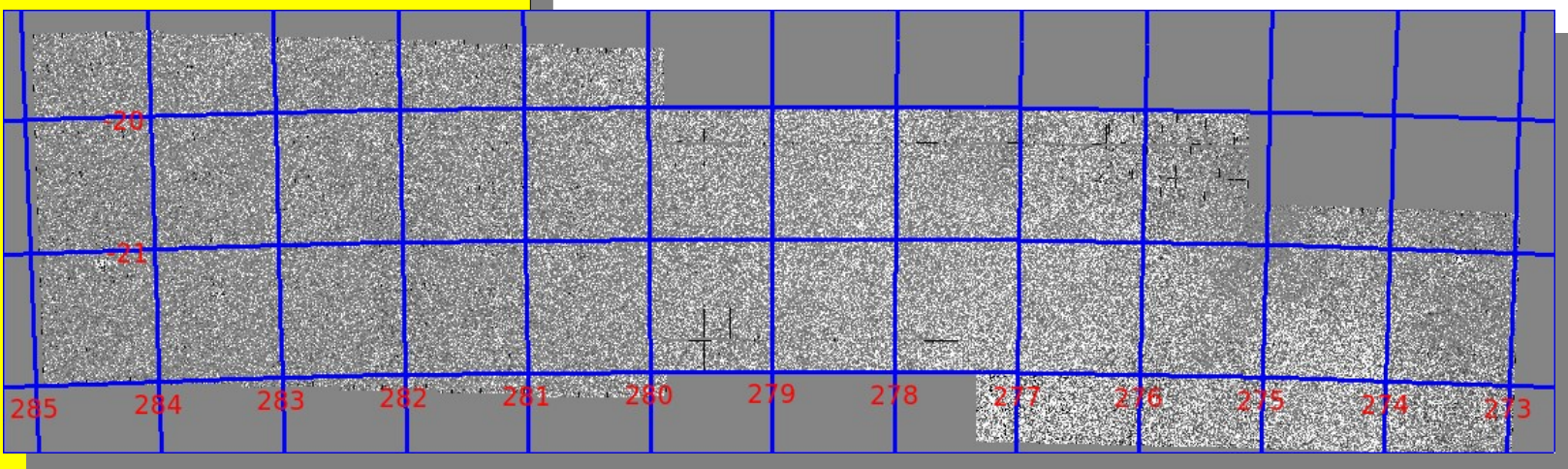


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Two tasks:

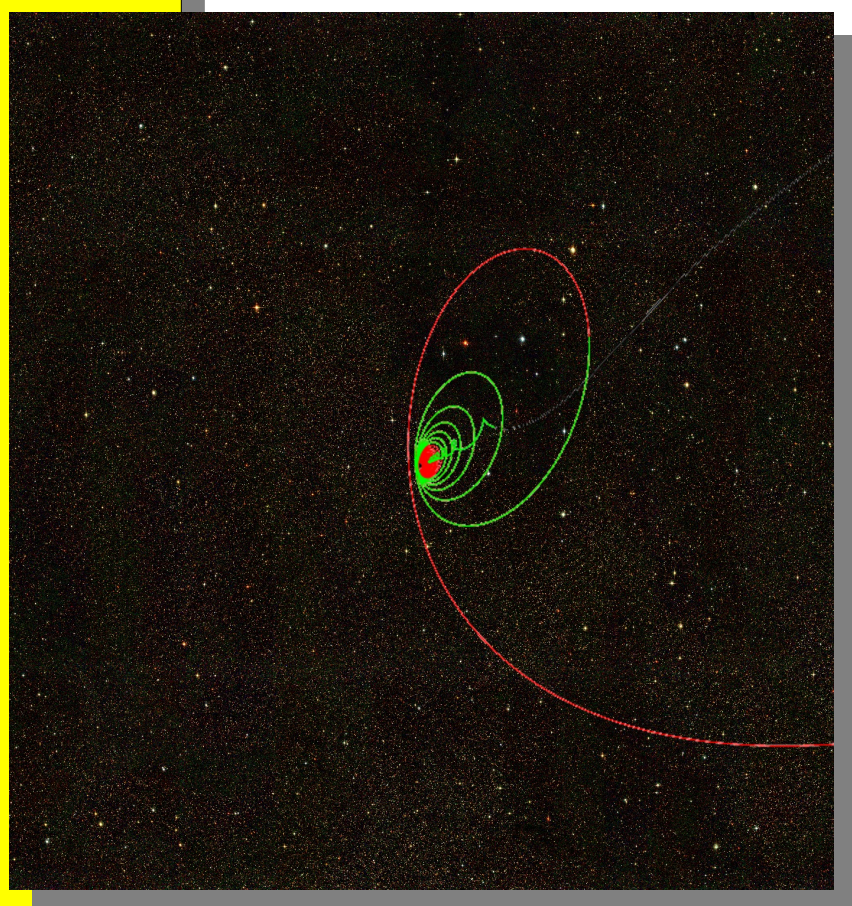
1) Discover a second target in the Kuiper Belt:

After the Pluto flyby, the space craft will have a small amount of reserve propellant. This will be used to alter course for second KBO. The ongoing search for this object involves data from the Subaru and Magellan, as well as CFHT. The MegaPipe images are being used as the astrometric reference frame. This search covers 30 square degrees of *r*-band data.



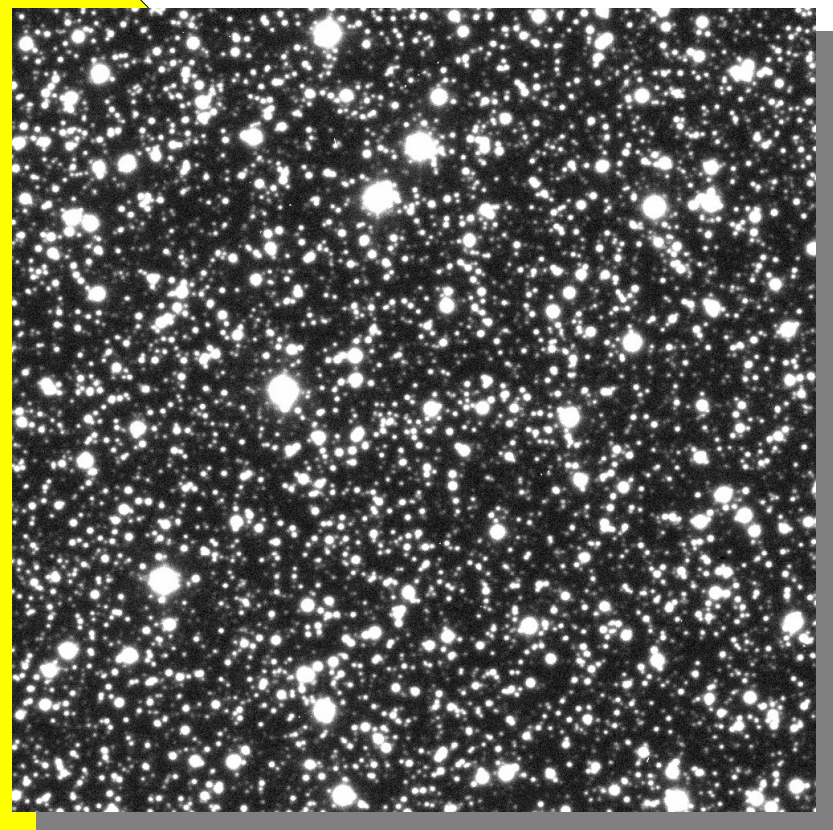
2) Guide the spacecraft's approach:

Between 45 and 6 days before the encounter, LORRI, the onboard detector will search the Pluto-Charon system for potentially hazardous debris. MegaPipe data is being used as the astrometric reference for this search. The figure shows the field rendered from the MegaPipe *gri* images. The green line shows the position of Pluto over the last 45 days of the approach, as seen from New Horizons

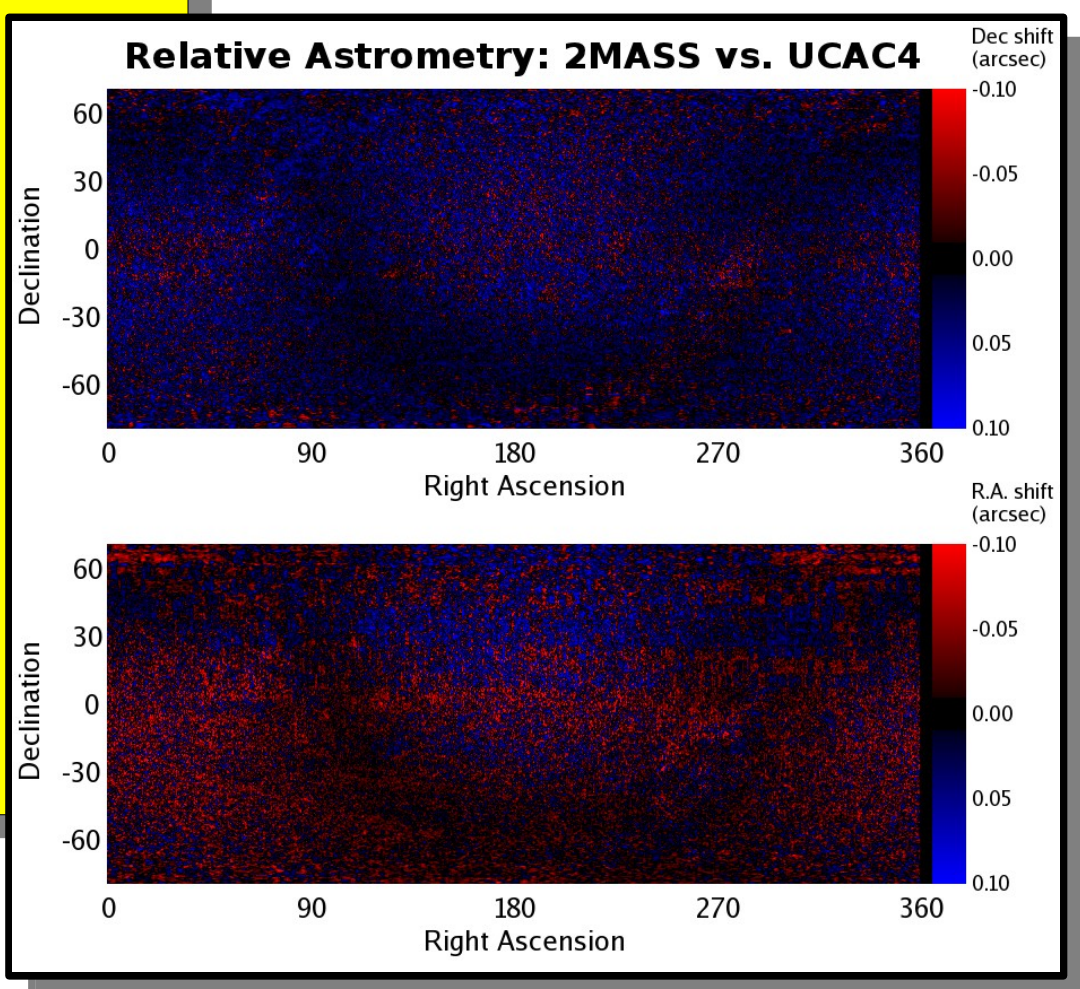


Crowding:

Pluto is currently crossing the galactic plane. The stellar density in this region of the sky is extremely high. There is a strong potential for confusion when matching stars in the images to stars in the reference catalog. The equations describing the distortion must be kept "stiff" to avoid spurious matches. The image is 3 arcmin on a side.



On the plus side, UCAC4, which is normally too shallow and sparse to be used with MegaCam images, can be used effectively. This is desirable since there are small but systematic errors in 2MASS, MegaPipe's usual astrometric reference. The offsets shown at right have a pattern with a 6 degree period in Dec, matching the 2MASS observation strategy



Method:

Step 1: Match each image to the external reference catalog and compute initial WCS

- Secure matches only: exclude stars with neighbors.
- Don't use n-th order polynomial in x and y (too many parameters).
- Model distortion as $r' = r(1 + a_2 r^2 + a_4 r^4)$

Step 2: Merge catalogs from each image to build intermediate catalog

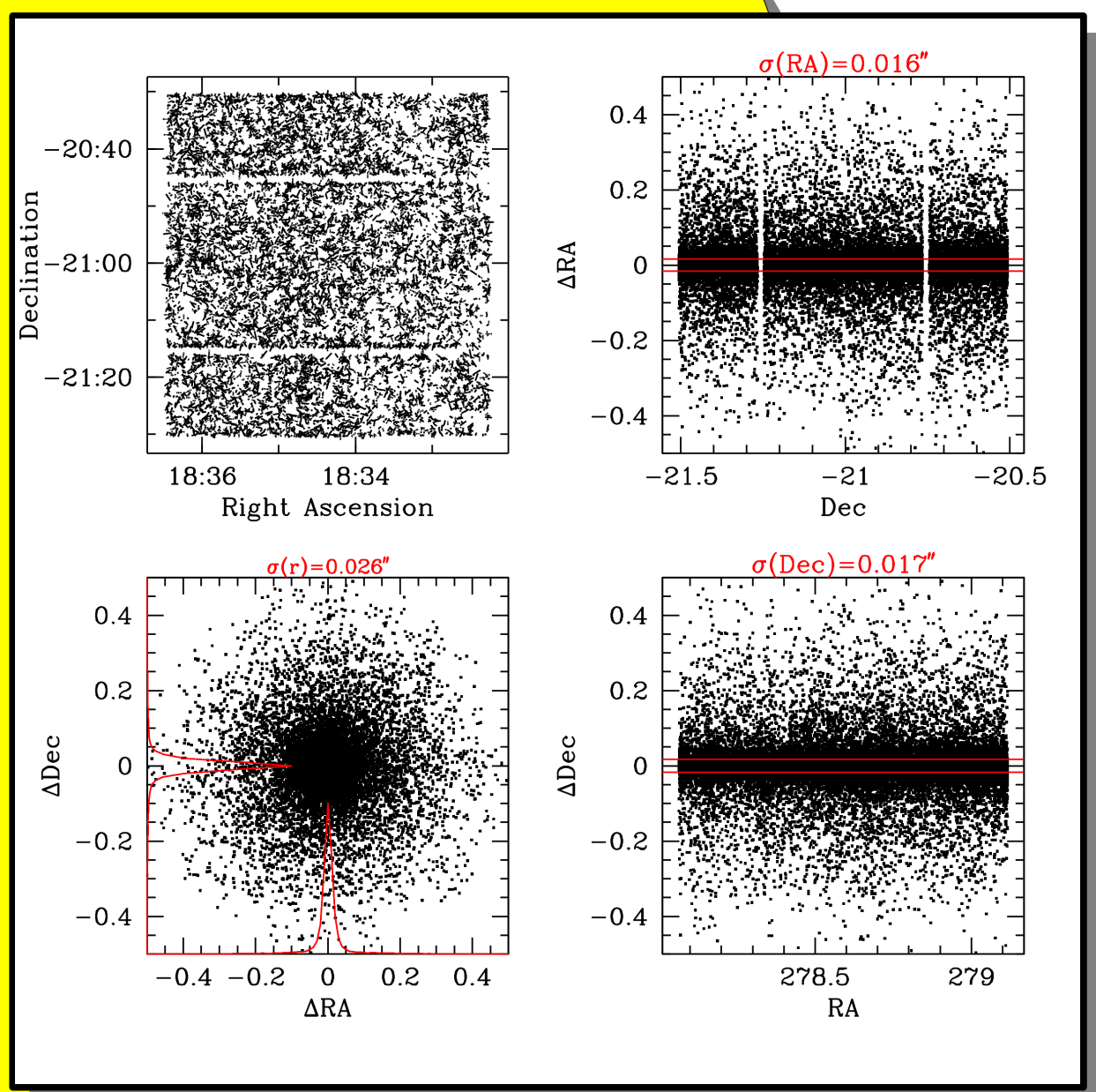
- a few hundred thousand sources per image
- match individual images to intermediate catalog
- iterate

Step 3: Merge all images and generate final catalog

- SWarp to combine images
- SExtractor (tweak parameters due to crowding)
- Calibrate individual images using this final catalog

Tests:

The various catalogs from the calibrated individual images were matched against each other and against the final catalogs and the residuals examined. For the Pluto encounter field, the catalogs in the *gri* bands were also checked against each other. The astrometric residuals were typically **0.02"**, as shown.



The positions and magnitudes of the Pluto encounter field catalog were used to simulate an image from the spacecraft's camera, LORRI. The catalog positions were convolved with LORRI's PSF. The simulated image was subtracted from a real image, after making small adjustments for the spacecraft's pointing and roll angle. Although small residuals (both positive and negative) reveal a bandpass mismatch between MegaCam and LORRI, the alignment is perfect, as shown

